IADC DEEPWATER WELL CONTROL GUIDELINES

2ND EDITION

IADC™

International Association of Drilling Contractors
10370 Richmond Avenue, Suite 760
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USA

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INTRODUCTION

Maintaining well control is critical to safe and successful drilling operations. This work, the 2nd edition of the IADC Deepwater Well Control Guidelines was authored by a task force of industry experts under the leadership of Louis Romo, BP, with guidance from Moe Plaisance, Diamond Offshore Drilling, Inc., executive advisor, who led the development of the original edition of this publication in 1998.

More than 80 subject matter experts representing drilling contractors, operators, service companies and equipment manufacturers participated in the update of these guidelines to develop a comprehensive document specific to subsea well control. This informative resource for safely managing well control risks addresses process safety & well integrity, well planning, equipment, training and drills, well control procedures and emergency response.

The new and revised content in the 2nd edition of the IADC Deepwater Well Control was developed by several work groups comprising volunteer subject matter experts.

This work comprises six chapters. Each is briefly described below, and the chairman of each group identified. Members of each committee are listed on the opening page of the chapter. For the user's convenience, a complete list of acronyms and definitions used in the IADC Deepwater Well Control Guidelines is included as an appendix.

- Operational Risk Management and Well Integrity, James Hebert, Diamond Offshore Drilling, Inc., chairman: This chapter reviews concepts and terms for establishment, maintenance, and verification of barriers to prevent loss of well control and maintain well integrity. This overview provides context to the remaining sections of the guidelines and how these practices interact to prevent the loss of well control.

- Well Planning, Brian Tarr, Shell, chairman: The Well Planning chapter discusses concepts and guidelines to help the rig team understand the relevance of well planning and well design to well control.

- Equipment, Pete Bennett, Pacific Drilling Services, Inc., chairman: The Equipment chapter describes typical well control equipment employed on floating rigs.

- Well Control Procedures, Earl Robinson, Murphy Exploration and Production Co., chairman: The Procedures chapter covers a range of kick prevention, detection and mitigation measures to maintain well control.

- Training and Drills, Benny Mason, Rig QA International, chairman: The Training and Drills chapter provides guidance for planning, conducting, evaluating, and continuously improving rig-based well control training and drills.

- Emergency Response, John Garner, Boots & Coots, chairman:

The Emergency Response chapter provides an overview of the activities and resources involved in preparation for and response to a well control emergency.

These guidelines are intended as an industry reference for rig personnel and as a framework to assist companies with their internal well control related processes and procedures.

IADC thanks the dedicated volunteers who developed this important work.

About the IADC Deepwater Well Control Guidelines

The IADC Deepwater Well Control Guidelines, 2nd Edition, was assembled by volunteer drilling-industry professionals with significant well-control expertise. These volunteers contributed their time, energy and knowledge in developing the IADC Deepwater Well Control Guidelines, 2nd edition, to help facilitate safe and efficient deepwater drilling operations.

The contents of this manual should not replace or take precedence over manufacturer, operator or individual drilling company recommendations, policies or procedures. In jurisdictions where the contents of the IADC Deepwater Well Control Guidelines might conflict with regional, state or national statute or regulation, IADC strongly advises adhering to local rules.

While IADC believes the information presented is accurate as of the date of publication, each reader is responsible for his own reliance, reasonable or otherwise, on the information presented. Readers should be aware that technology and practices advance quickly, and the subject matter discussed herein may quickly become surpassed. If professional engineering expertise is required, the services of a competent individual or firm should be sought. Neither IADC nor the contributors to these guidelines warrant or guarantee that application of any theory, concept, method or action described in this book will lead to the result desired by the reader.

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CHAPTER 1

OPERATIONAL RISK MANAGEMENT AND WELL INTEGRITY

Committee Members and Contributors

James Hebert (Chairman), *Diamond Offshore Drilling Inc.*

David Foster, *Transocean*

Bill Nelson, *DNV GL*

John Shaughnessy, *Consultant*

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1.1 SCOPE

The objective of the IADC Deepwater Well Control Guidelines (DWWCG) is to provide guidance for maintaining primary well control, applying secondary well control methods and responding to an emergency if a blowout occurs. The Operational Risk Management and Well Integrity (ORM and WI) Chapter is intended to provide an overview for establishing and maintaining the wellbore barriers that prevent the loss of well control (LWC). Each chapter of the guideline is intended to help the rig team understand a new topic and how it relates to maintaining control of the well.

ORM concepts can provide context for how the remaining chapters relate to one another. In summary, the relationships can be visualized as shown in Figure 1.1.

FIgure 1.1 mimics a Bow-Tie Diagram of the actions for maintaining well control. The Chapters on the left side of the event correlate with establishing preventive barriers, whereas sections on the right side of the event correlate with escalation barriers and responses to reduce the consequences. Barriers and Bow-Tie Diagrams are covered in more detail in the sections that follow.

1.2 OPERATIONAL RISK MANAGEMENT

Operational Risk Management (ORM) is used by the IADC to describe how operational and asset integrity is ensured through the management of major hazards. Major hazards are defined as those that pose a significant risk for:

- Multiple fatalities or permanent total disabilities
- Extensive damage to the installation
- Severe impact to the environment.

A key aspect of ORM is to use a systematic approach for the installation, testing and maintenance of barriers, thereby reducing the probability of a Major Accident Event (MAE).

The IADC Deepwater Well Control Guidelines is intended to provide a recommended practice to its membership for maintaining control of the well for floating drilling operations. The Operational Risk Management and Well Integrity Chapter provides an overview of the terms, concepts and practices relating to managing the barriers required to maintain well control. As indicated in FIgure 1.2, Well Integrity (WI) is a subset of ORM and is focused specifically on well construction and maintaining control of the well.

Note: In recent years there has been an increasing trend within the upstream industry to use the term "Process Safety" to refer to the risk management of drilling operations. However, process safety already has a well-established definition and application in the chemical industry and in downstream activities such as oil refining. It has a narrow focus on preventing fires, explosions and accidental chemical releases, with the main consideration and concern being public safety. Within the United States, the Occupational Safety and Health Association (OSHA) introduced regulation specific to process safety management which explicitly focuses on highly hazardous chemicals. Process safety focuses on a defensive approach for protection of a well-defined, consistent process which normally occurs within a narrow set of parameters. Operational Risk Management (ORM) is considered more appropriate for the larger set of potential hazards associated with upstream operations. For offshore drilling, ORM emphasizes a proactive and dynamic approach to the creation and continuous management of barriers that change depending on the operating condition. Consequently the IADC DWWC Guidelines will not refer to "Process Safety" in relation to drilling, completion or any other upstream well operations.

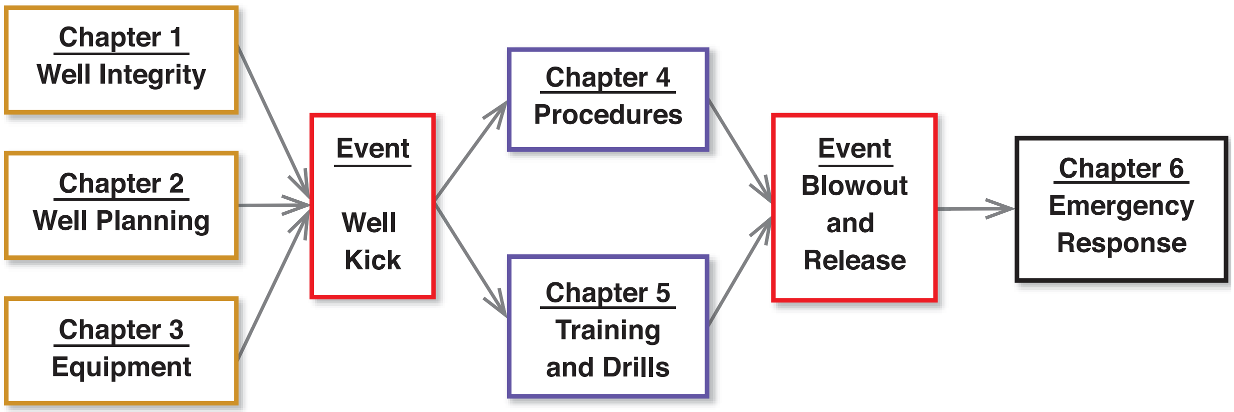

FIgure 1.1 — IADC Deepwater Well Control Guidelines - Chapter Relationship.

FIgure 1.2 — Relationship of Operational Risk Management, Well Integrity and Well Control.

1.2.1 Operational risk management vs. personal safety

ORM focuses on preventing Major Accident Events (MAEs) such as large hydrocarbon releases, explosion, fire or flooding which could cause serious injury or fatality to multiple personnel, severe damage to the vessel or significant pollution. In contrast, personal safety focuses on preventing injuries such as slips, trips or falls which normally involve only one or several individuals performing manual tasks. FIgure 1.3 is intended to illustrate this difference, and that Major Accident Events tend to have lower frequency but higher severity when compared to personal safety accidents.

Just as operational risk and personal safety have different risk profiles regarding severity and frequency, they also have different types of hazards which can cause an incident. For safety management of offshore operations it is important to focus on both personal safety and operational risk. There is a specific need to plan, monitor and discuss the MAE hazards and to assign responsibility to ensure they are controlled and monitored during all phases of operation. It is also important to ensure that the risk management knowledge that is developed during system design and operational planning is transferred to the rig team so they will have full knowledge of the hazards involved and the strategies for preventing MAEs. Expanding the pre-tour and pre-job meetings for MAE hazards could be one option for communicating to the rig team and explaining these hazards and how to prevent them.

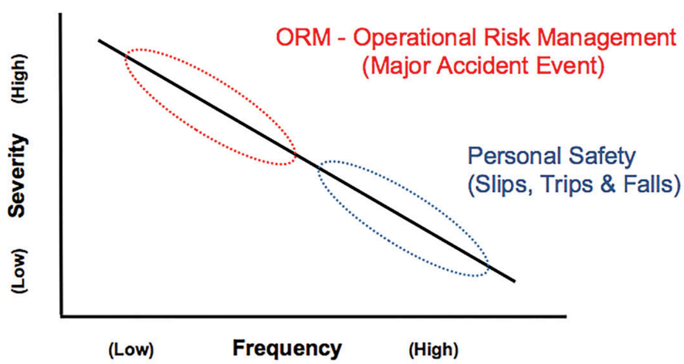

FIgure 1.3 — Relationship between Operational Risk and Personal Safety.

1.2.2 Preventive barriers

Preventive barriers are considered to be hazard control systems and can be visualized as slices of "Swiss Cheese" that intervene to prevent a hazard from leading to an accident. As no single barrier is perfect, the holes in each slice indicate weakness in the barrier that may allow them to be defeated or bypassed. This is illustrated in FIgure 1.4. The goal of effective ORM is to have multiple barriers arranged where they support each other, i.e., the holes never line-up, thereby ensuring the system as a whole is effective. It is also important that barriers are independent to the highest degree possible, so that failure of one barrier doesn't lead to the failure of others.

To ensure that preventive barriers are not compromised, it is important for all personnel to understand the potential MAEs and know their role in managing the availability and effectiveness of the preventive barriers. When all rig personnel have this awareness and responsibility, operational and system integrity can be established and maintained. During pre-tour or pre-job meetings, it is important to discuss the status of the preventive barriers in place, whether they have been compromised or degraded over time, and who is responsible to monitor and cross check to ensure they remain effective.

Barriers can generally be categorized as follows:

- Equipment: Passive physical barriers, such as mud, csing and cement,used to conrol the well formation pressure to prevent a blowout or environmental release of hydrocarbons from occurring. Additional, or secondary equipment barriers, such as the BOP systems, are

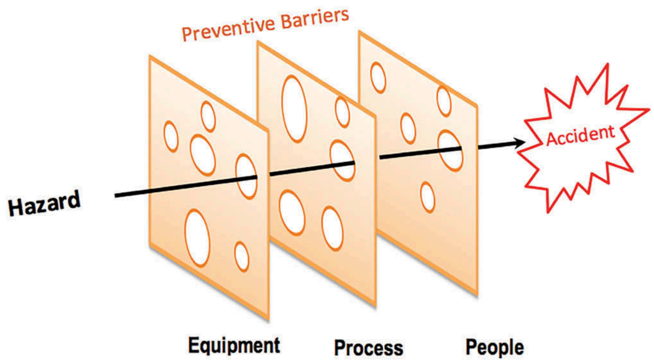

FIgure 1.4 — "Swiss Cheese" barrier model.

designed to intervene in case the other physical barriers fail. Equipment barriers are sometimes also referred to as technical barriers.

- Process: The plan or methodology consisting of a management system (SEMS, Safety Case, etc.), operating procedures, maintenance programs, alarms and process monitoring to ensure that operations are conducted with barriers in place and within operational limits.
- People – Competent personnel understanding preventive barriers, following procedures while understanding equipment limitations, with knowledge of who is responsible for monitoring and maintaining the barriers, and with the authority to take effective preventive action when required.

A significant characteristic of MAEs is that they usually result from complex combinations of equipment failures, human errors, and/or software failures. Human intervention is sometimes the last and most important line of defense to prevent MAEs such as loss of well control that leads to a blowout.

1.2.3 Equipment barriers

Physical barriers are classified as either primary or secondary, and during conventional drilling or completion operations this usually involves fluid hydrostatic as the primary barrier while cement, the BOP and other mechanical components form the secondary barrier. This will be covered in more detail in the Well Integrity section of this chapter.

There are several documents which provide requirements and guidance for the design, installation and testing of physical barriers, which include:

- API Spec 16A: Specification for Drill-through Equipment;
- API Spec 16D: Specification for Control Systems for Drilling Well Control; Equipment and Control Systems for Diverter Equipment;
- API Standard 53: Blowout Prevention Equipment Systems for Drilling Wells;
- API Standard 65-2: Isolating Potential Flow Zone During Well Construction;
- API Recommended Practice 59: Recommended Practice for Well Control Operations;
- API Recommended Practice 96: Deepwater Well Design and Construction;
- NORSOK D-010: Well Integrity in Drilling and Well Operations.

Since the specific design requirements and principles of well barriers are well documented by the above references, they need not be covered in detail within the scope of this guideline. The focus instead will be the operational and quality assurance aspects of primary and secondary well barriers, and the rig-based practices needed to support monitoring and maintaining them.

1.2.4 People and process barriers

From an operational standpoint, the effectiveness of barriers is directly related to the rig team's understanding, monitoring capabilities, and ability to take appropriate action to ensure the effectiveness of the barriers.

As daily operational plans are developed, it is important to consider:

- What limits are we working to?
- What barriers are in place before starting an activity?
- How and when were those barriers verified?
- How will barriers be continuously monitored and who is responsible?
- Will barriers be installed or removed as part of this activity?
- How can the planned activity alter or impact any barriers?

The rig-based team should discuss and coordinate these topics to ensure that it is functioning effectively to monitor the potential threats to preventive barriers during drilling, tripping, casing and cementing. Understanding and coordinating the main barriers, as well as assigning the responsible persons to monitor — along with their required actions — are key factors of the operation's success. This coordination can be accomplished during the Supervisor's planning meetings (through daily work instructions), pre-tour meetings, and pre-job meetings. During these coordination sessions, operational barriers and potential threats to their effectiveness should be reviewed and discussed to ensure all personnel involved in the operation are cognizant of current conditions and understand acceptable conditions. The status and effectiveness of the procedures, training and competency, drills, maintenance, etc., should all be confirmed. Finally, actions should be identified that ensure the barriers remain effective throughout the job.

1.2.5 Escalation barriers

In addition to preventive barriers, there are escalation barriers that focus on the control of the situation to limit the accident severity. The combination of preventive and escalation barriers can be visualized by what is known as a "Bow-Tie Diagram." Bow-Tie analysis is a risk assessment method that captures the hazards and preventive barriers on the left side, the "Top Event," which could lead to a MAE, in the middle, and escalation barriers and consequences on the right side. Typically, a separate Bow-Tie analysis is developed for each top event, detailing the relationships of the hazards, preventive barriers and escalation barriers. The objective of understanding this relationship is to ensure that multiple barriers are in place for each hazard and that barriers are independent of each other. A simplified example, illustrating the concept for a blowout stemming from loss of well control, is shown in Figure 1.5. The individual hazards can come from the wellbore, equipment failure, and/or operating procedures. Assignments of responsibility and the criticality of the barrier can be made in the Bow-Tie analysis to assist each employee in clearly understanding their role in ensuring the barriers are monitored and maintained.

1.2.6 Effective operational risk management programs for well control

Every offshore installation should already have in place a broad safety management program covering the risks associated with MAEs. Well control-related MAEs such as underground blowout and blowout may represent the dominant risk scenarios for the installation and therefore well control issues should be addressed in the overall safety management program through the following activities:

- Systematic identification of the preventive and escalation barriers that can be used to prevent or mitigate well control-related MAEs;
- Systematic design of equipment, processes, and procedures to support the maintenance and operation of the well control barriers;
- Procedures to test and verify the effectiveness of barriers;
- Designation of personnel responsible for continuous monitoring and maintenance of each barrier;
- Development of procedures describing appropriate actions to be taken if barriers fail or are degraded;
- Incident investigation, root cause analysis, lessons learned, and corrective actions for incidents involving degraded or failed well control barriers;
- Development of training and decision support tools to ensure that well control personnel are competent for normal operation and will respond appropriately during well control incidents to prevent the occurrence of MAEs.

The operational activities relating to managing the threat to the installation posed by the hazard of hydrocarbons in the well will be covered in more detail in the following Well Integrity section.

1.3 WELL INTEGRITY MANAGEMENT

Within the overall system of ORM, there are specialized disciplines such as Well Integrity and Water-tight Integrity. Well Integrity Management addresses the specific major hazard of hydrocarbons in formations penetrated by the well bore.

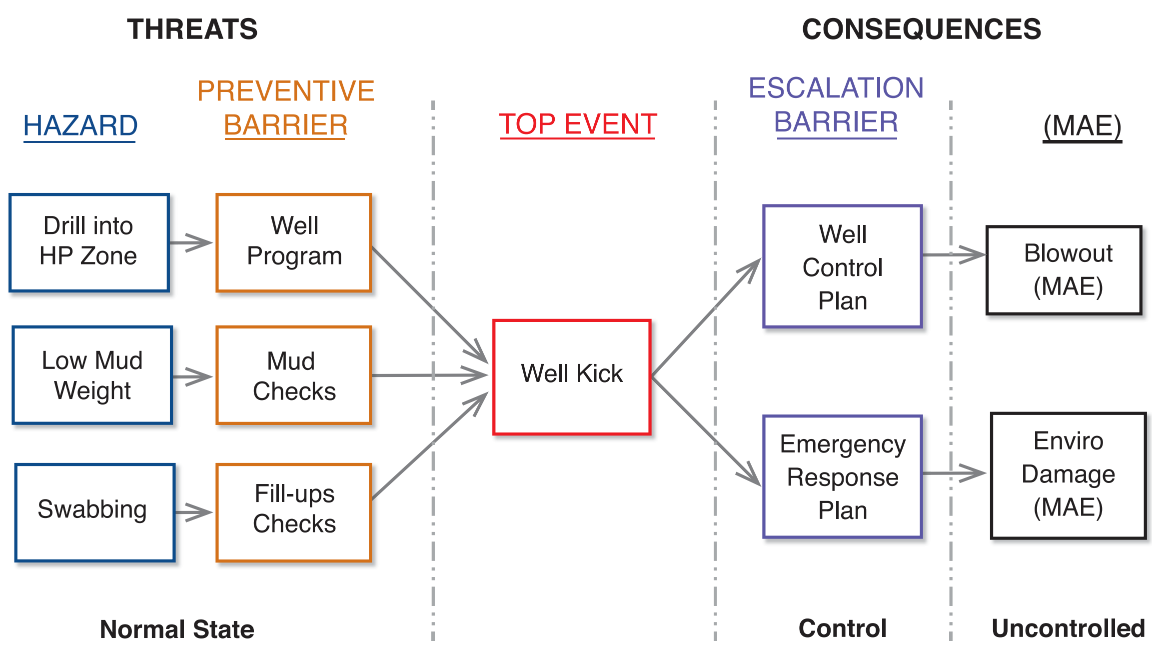

Figure 1.5 — Example Bow-Tie Analysis Diagram for a Well Kick while drilling.